Hydrogen and Fuel Cell R&D at the Oak Ridge National Laboratory

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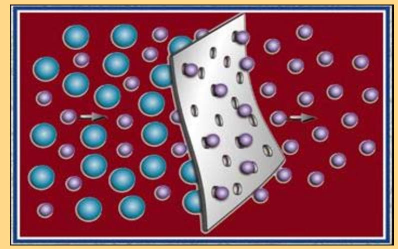
Southeastern Regional Hydrogen Forum

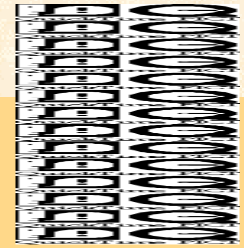
April 29, 2003

www.ornl.gov/EERE

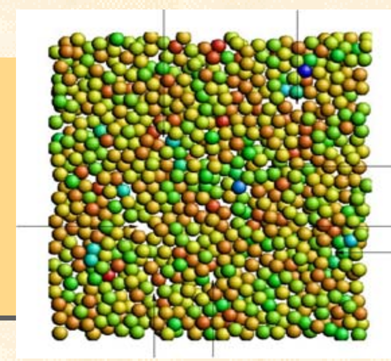
ORNL is researching several hydrogen production and storage technologies

- **Hydrogen Production**
  - **Separations - inorganic membrane technology**
  - **Thermochemical - iodine-sulfur process**
  - **Photobiological - hydrogen from engineered strains of biomass algae**





- **Hydrogen Storage**
  - **Bulk amorphous alloys**
  - **Carbon materials**
  - **Recycling of sodium borohydride**
  - **Development of a H_2 gas sensor**

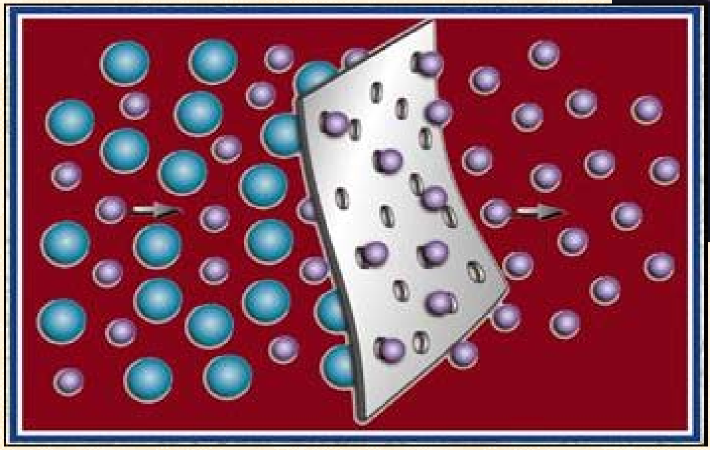


Atom-size holes

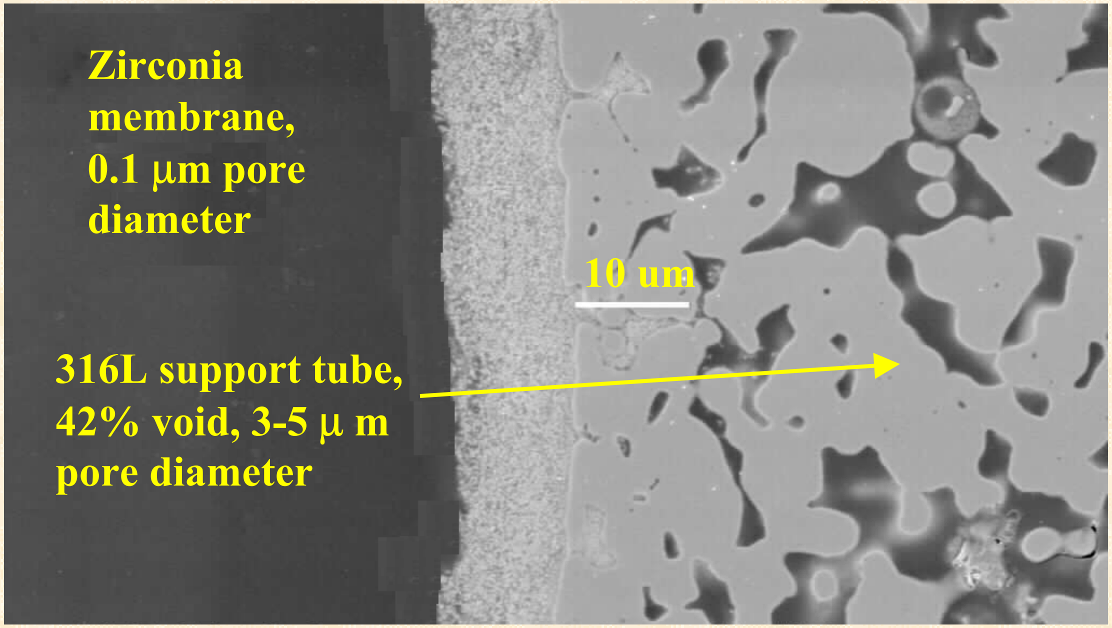
Development of a Porous Inorganic Membrane Hydrogen Separation Device

Objective/Challenge

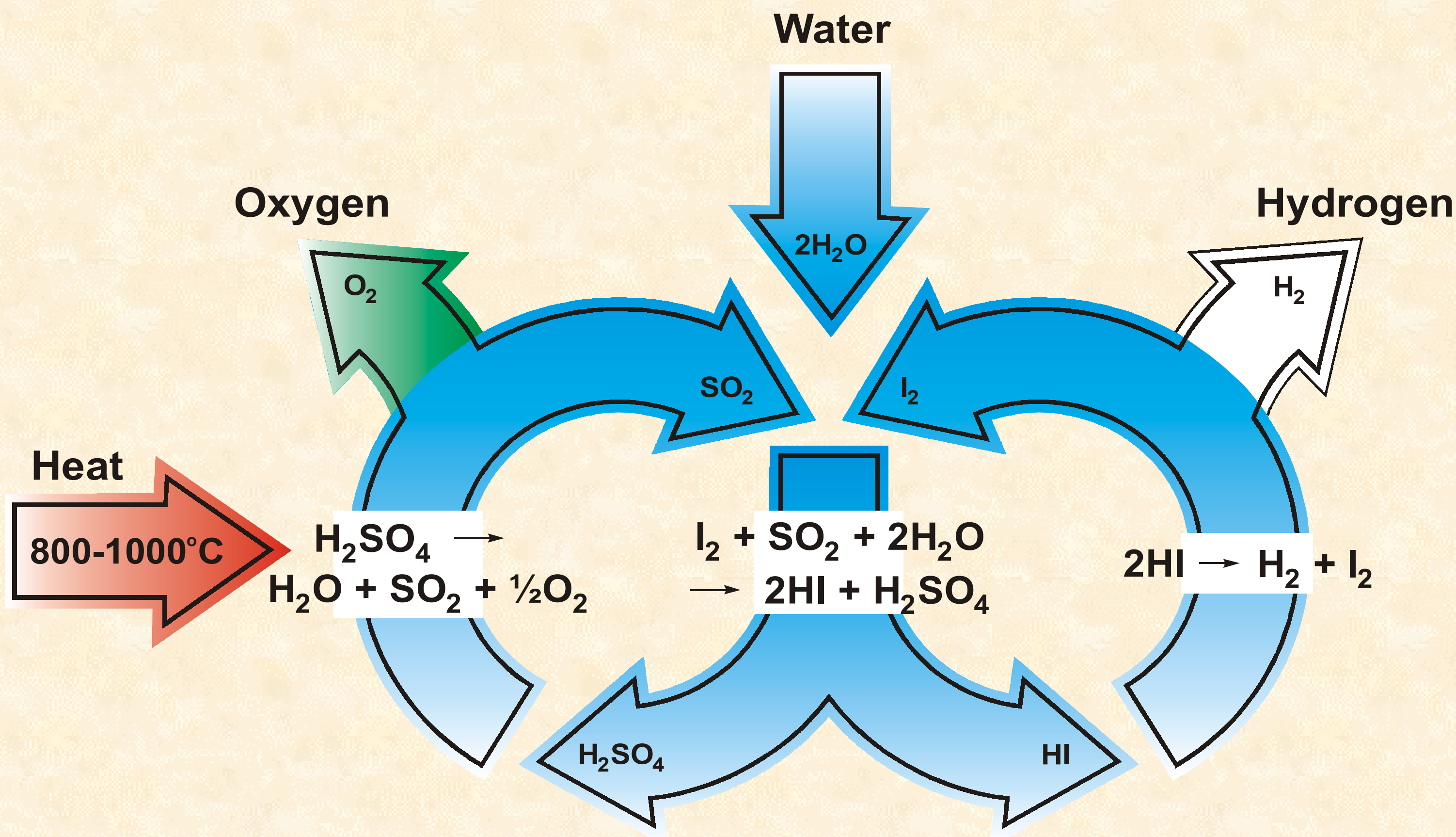
- Develop a Compact and Efficient Hydrogen Separation Device for the Purification of Hydrogen
- Develop, Through Experimental and Theoretical Approaches, Gas Separation Membranes that Meet Rigorous Performance Criteria for Flux, Separation, and Hydrogen Purity
- Transport is via molecular diffusion
- Separation may occur by:
  - Molecular sieving
  - Knudsen diffusion
  - Surface flow



Nanoporous Inorganic Membranes for High Selectivity Hydrogen Separation



Iodine-Sulfur Thermochemical Process Uses High-Temperature Heat and Water to Produce H_2



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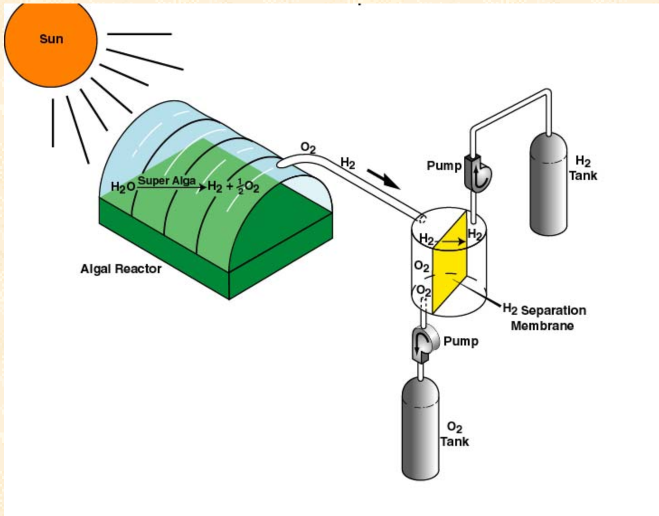
Hydrogen production from photosynthetic water splitting by designer alga

- This research involves the creation of:

- Designer alga by genetic insertion of hydrogenase promoter-programmed polypeptide proton channels in photosynthetic thylakoid membrane
- Smaller chlorophyll antenna
- O_2-tolerant hydrogenase

This project aims to deliver a H_2-production technology that can meet the DOE goal of $10/MMBtu



Vision of H_2 production from designer alga

Partners: NREL and UC Berkeley

Designer alga H_2 production could be an attractive new energy business

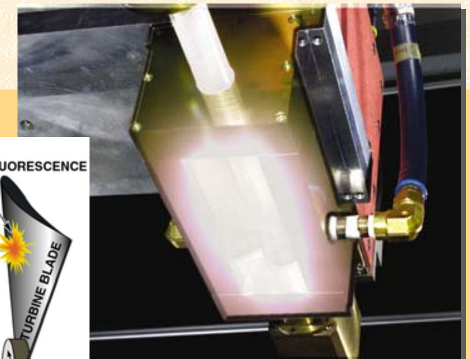
Designer-alga H_2 productivity	H_2 energy value produced	H_2 cash value at production site	Number of cars that could be supported
21,519 Kg H_2 / acre.year	2,419 MMBtu / acre.year	$18,622 / acre.year	140 cars / acre.year

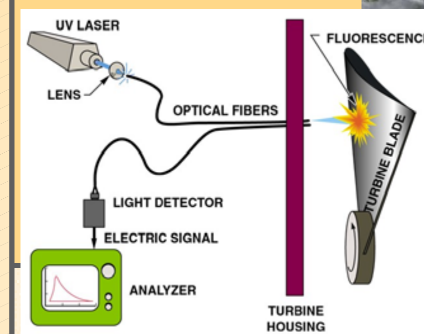
13.3 million acres (40% of CRP set-aside land) would be needed to produce enough hydrogen to power all U.S. cars

Assumes: the value of H_2 at production site will be $10 per 1.15 MMBtu and 10% solar energy conversion efficiency for the designer alga H_2 production process.

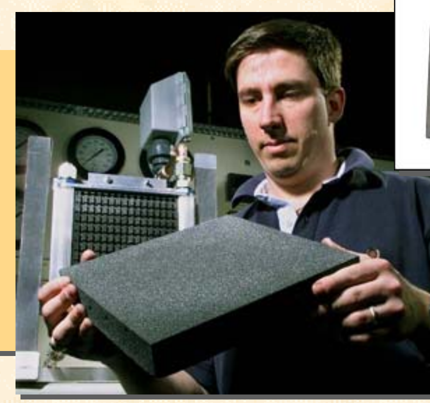
ORNL's fuel cell program focuses on component development & manufacturing

- Metallic and carbon bipolar plate development for PEM applications
- Carbon-based heat exchangers and humidifiers
- Sulfur mitigation catalysts





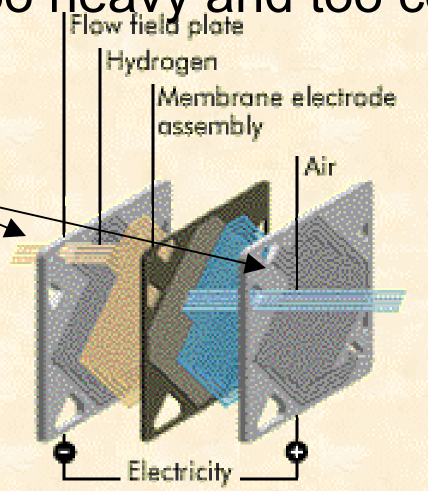
- Fiber optic temperature sensors
- New bi-directional DC/DC converter ideal for fuel cell power management
- Cell and materials modeling



Bipolar Plate Development

Challenge: Current technology for bipolar plates for PEM fuel cells (machined graphite) is too heavy and too costly.

Bipolar Plate is
- *Cell electrode*
- *Sealing surface*
- *Flow field for gas*

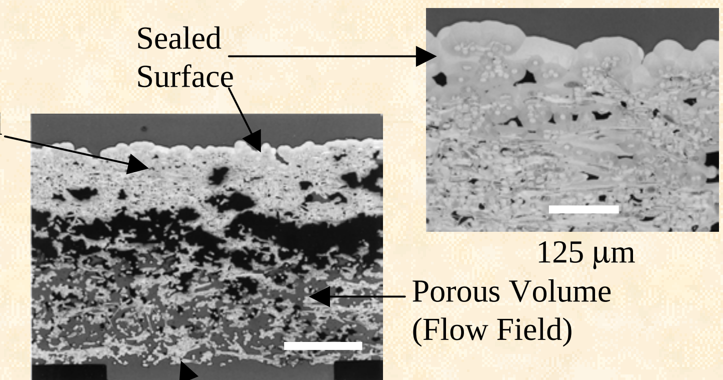


PEM Fuel Cell

Bipolar Plates Must
- *Be low cost*
- *Not corrode*
- *Have high electrical conductivity*
- *Have sufficient strength*
- *Prevent gas leakage*

Answer: Carbon fiber material, sealed with chemical vapor infiltrated carbon.

Advantages of Approach
- *Continuous or semi-batch process*
- *Carbon does not corrode*
- *Low cost (less than $1/plate)*
- *High conductivity*
- *Impermeable*
- *Thin (2 mm)/lightweight*
- *Built in flow field*



Cross-Section of Bipolar Plate

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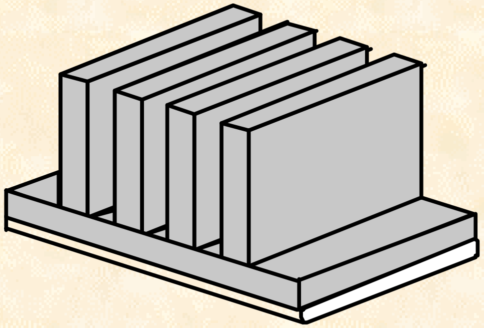
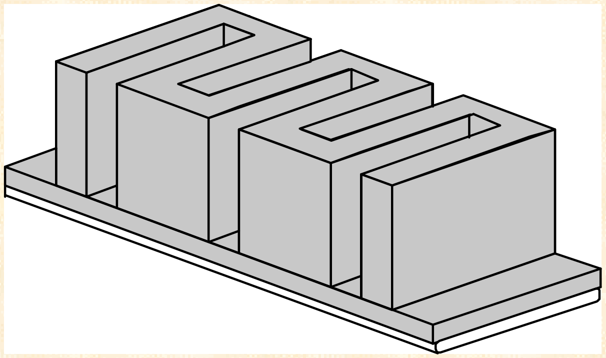
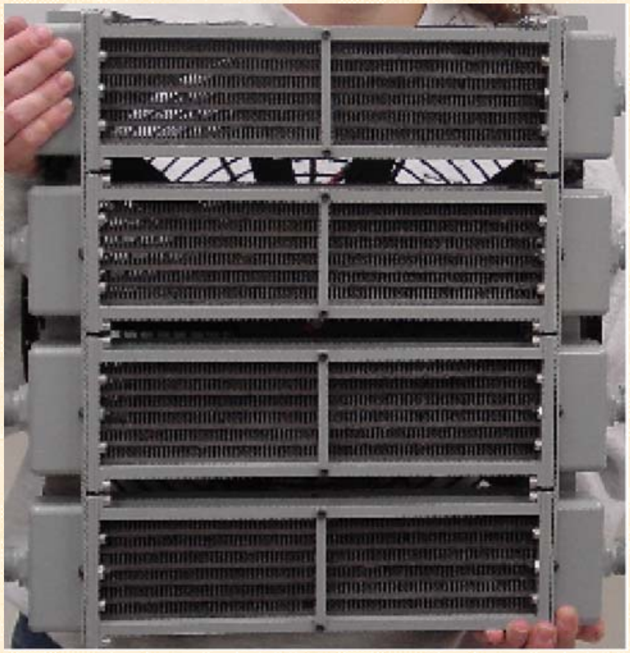
Graphite Foam Designed Radiators (ORNL)



Standard fin design



Corrugated fin design



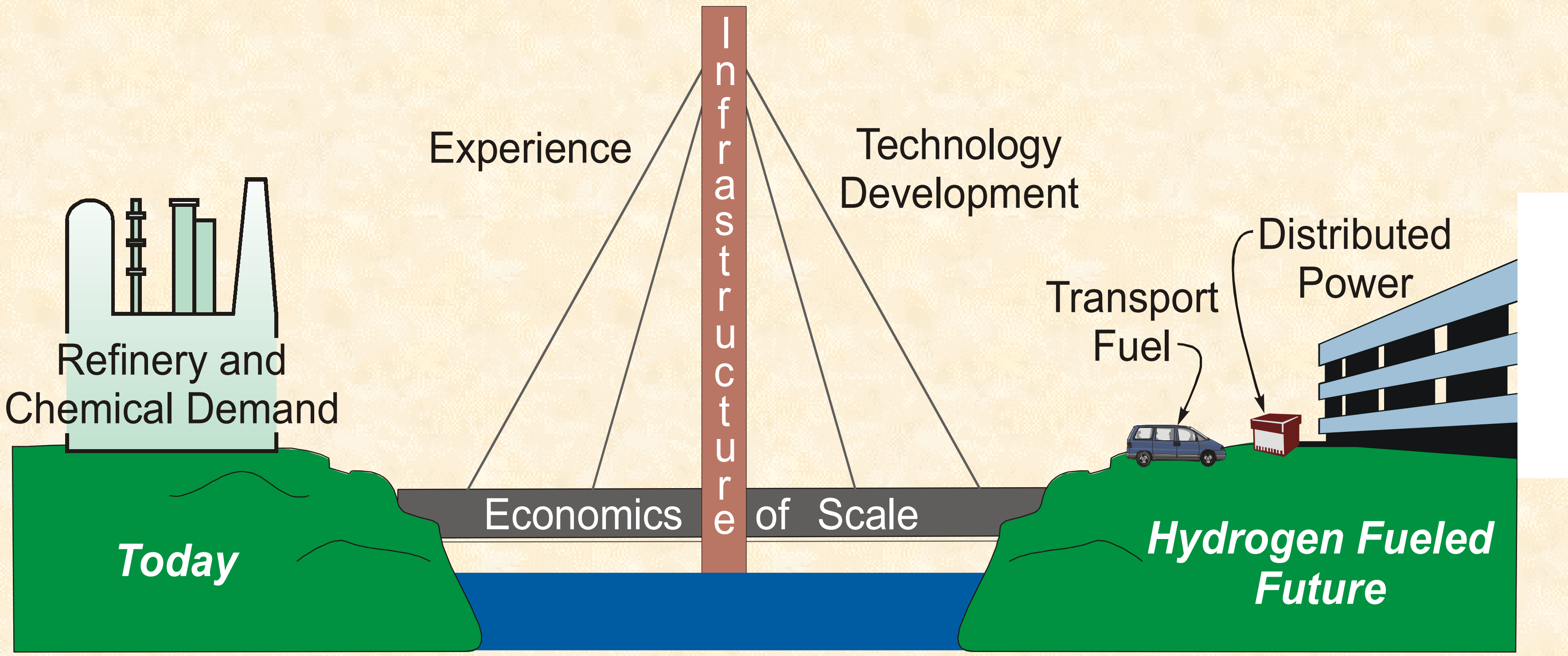
- **Innovative radiator designs utilize the high surface area of the graphite foam**
- **Foam radiators design after standard aluminum radiators have potential for 10% to 20% improvement**
- **Innovative designs that utilize much more of the surface area have a potential for significant increases in performance**

ORNL is research infrastructure issues

- Combined heat and power systems utilizing fuel cells
- Transition to a hydrogen economy with high efficiency engines and hydrogen-rich fuels

- Modeling - transportation fuels (demand and supply) data and models

Growing Hydrogen Demand Creates a Bridge to Fuel Cell Vehicles and a Hydrogen Economy



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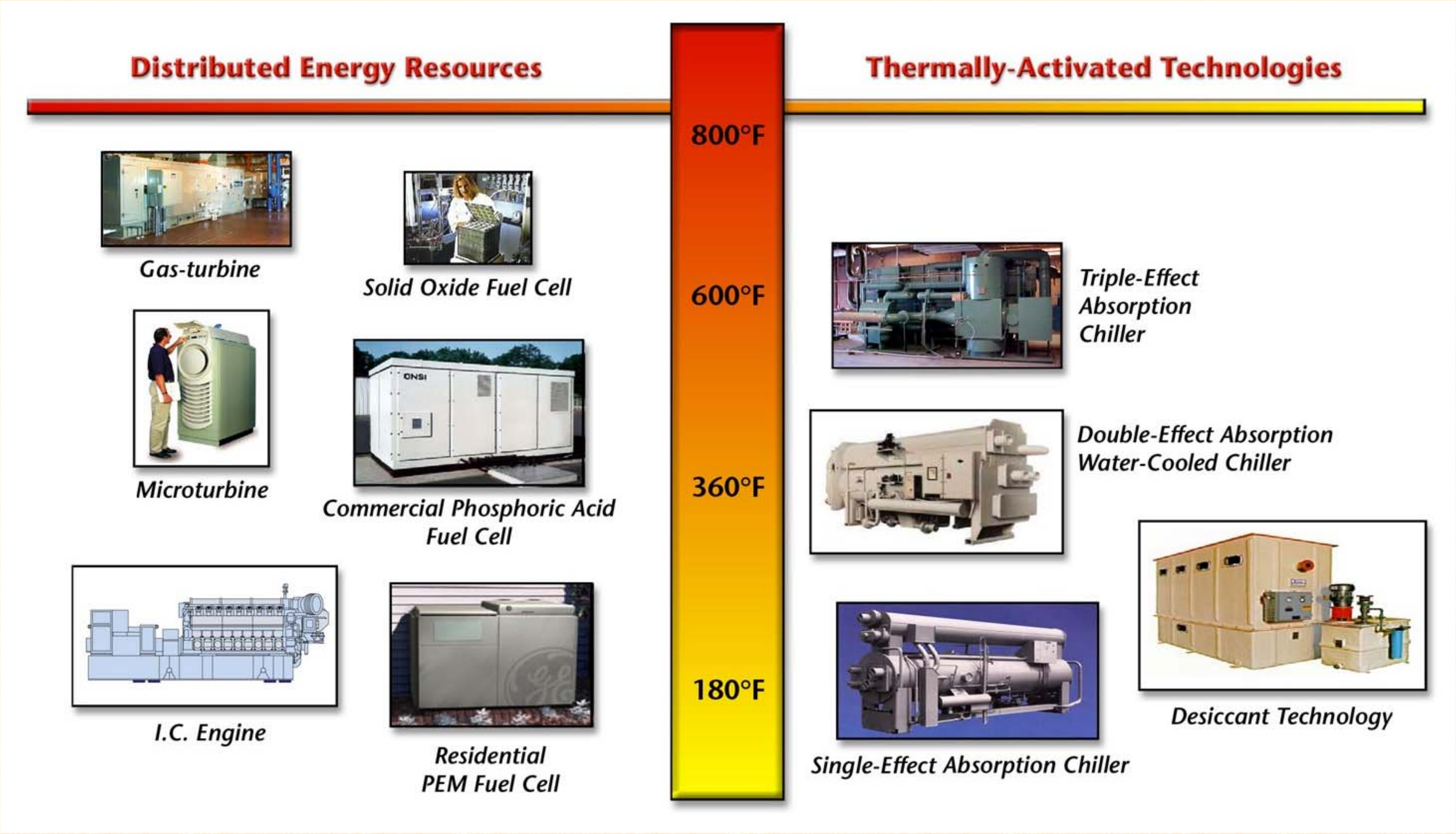
Combined heat & power technologies are being developed to raise system efficiencies



Fuel Cell Power Plant and Enthalpy Recovery Wheel at ORNL

- **UTC phosphoric acid fuel cell**
  - **200 kW—1/3 of building electricity**
  - **450,000 Btu/hr hot water @ 250°F used to heat building**
  - **Increases resource efficiency from 33% to 59% by combining building heating and power generation**

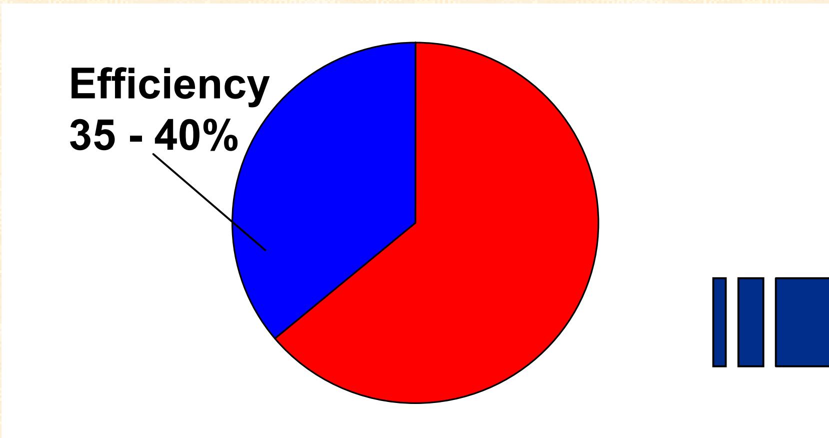
- **SEMCO enthalpy recovery system**
  - **Recovers enthalpy from exhaust air**
  - **Controls humidity of supply air in selected areas**

Heat recovery from PEM fuel cells

This Plug Power fuel cell at ORNL produces 2.5–5 kW of electricity. Options for waste heat recovery are being explored

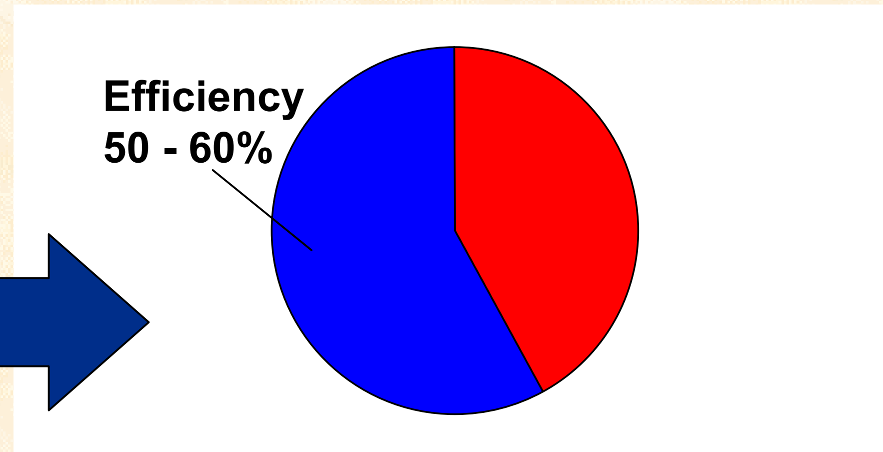
Improving engine efficiency to enable the transition to a hydrogen economy

Today's Engines



R&D

Advanced Combustion Engines



Losses:

- Emission Controls 3 – 8%
- Exhaust 12%
- Thermodynamic Combustion 16 – 19%
- Heat Transfer 14%
- Mechanical Pumping 6%
- Friction 5%

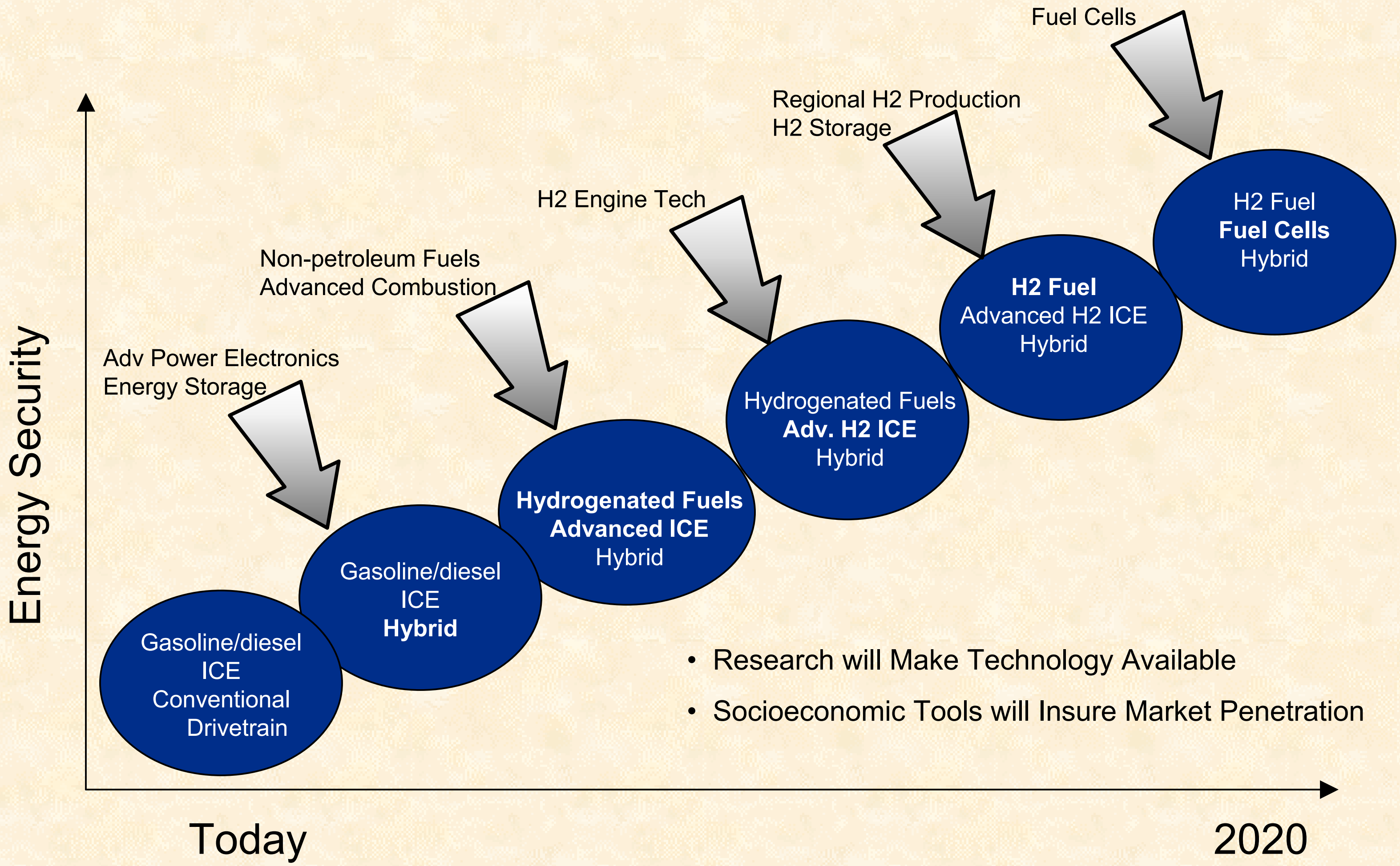
Potential Paths

- Advanced Combustion Regimes
- Advanced Control Strategies
- Waste Heat Recovery
- Reduced Friction Coatings
- Reduced Injection Pressure
- Thermo-electrics
- Engine Electrification
- Enabling Fuels

Losses:

- Emission Controls 1 – 2%
- Exhaust 8%
- Thermodynamic Combustion 14%
- Heat Transfer 10%
- Mechanical Pumping 4%
- Friction 4%

Energy Security Pathway to Fuel Cell Vehicles and Hydrogen Economy



- Research will Make Technology Available
- Socioeconomic Tools will Insure Market Penetration